

Designing Craters: Creating a Deep Impact

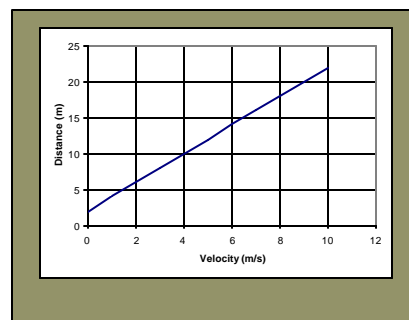
Predicting Crater Size

TEACHER GUIDE

BACKGROUND INFORMATION

One of the biggest differences between science in the classroom and science in the lab is what happens *after* an experiment has been conducted. In the classroom, a report is usually written that ends with a conclusion, discussing whether or not the data showed what was expected and what factors might have contributed to inaccuracies in the data. After that, the students move on to the next topic.

In the scientific world, one experiment can lead to more questions or to a reevaluation of the scientist's thinking about a phenomenon. Experiments are refined and repeated or new ones are designed. This activity attempts to bring this kind of thinking into the classroom, encouraging the students to really look at what they came up with, how that information might be used, and what further testing might be needed. More specifically, your students will be practicing looking for patterns in data and trying to use those patterns to make predictions.



It is important to note that we are not expecting students to derive a "correct" formula for determining final crater size in this activity. Scientists do have a good understanding of the general factors affecting crater size; however, the proportionality constants depend upon the specific materials involved in the impact. (See Appendix B for more information about cratering). For classroom scale cratering events, crater diameter should be proportional to the sixth to fourth root of the impactor's kinetic energy - a difficult relationship to uncover in classroom data. There should, however, be some recognizable patterns that can be used to make predictions over a limited range of variables. See the *Student Anticipations* section for more information about what you can expect from your students.

NATIONAL SCIENCE EDUCATION STANDARDS ADDRESSED

Grades 5-8

[Science as Inquiry](#)

(View a full text of the [National Science Education Standards](#).)

Abilities necessary to do scientific inquiry

- Develop descriptions, explanations, predictions and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Use mathematics in all aspects of scientific inquiry.

Grades 9-12

[Science as Inquiry](#)

Abilities necessary to do scientific inquiry

- Formulate and revise scientific explanations and models using logic and evidence.

PRINCIPLES AND STANDARDS FOR SCHOOL MATHEMATICS ADDRESSED

(View a full text of the [Principles and Standards for School Mathematics](#).)

Grades 6-8

[Data Analysis and Probability](#)

Develop and evaluate inferences and predictions that are based on data

- Make conjectures about possible relationships between two characteristics of a sample on the basis of scatterplots of the data and approximate lines of fit.
- Use conjectures to formulate new questions and plan new studies to answer them.

[Algebra](#)

Understand patterns, relations, and functions

- Represent, analyze, and generalize a variety of patterns with tables, graphs, words, and, when possible, symbolic rules.

Analyze change in various contexts

- Use graphs to analyze the nature of changes in quantities in linear relationships.

Use mathematical models to represent and understand quantitative relationships

- Model and solve contextualized problems using various representations, such as graphs, tables, and equations.

MATERIALS

- Materials used for the initial cratering experiments
- Student data charts and graphs from "[Graphing Your Data](#)" activity in previous module section, all copied onto overhead transparencies and copied for distribution to groups.
- Student Handouts, "[Looking for Patterns and Making Predictions, Part 1](#)" and [Part 2](#)
- Teacher Overhead Transparencies: "[Common Patterns](#)," "[Best-Fit Lines](#)," and "[Finding a Formula for a Line](#)."
- All posters presented during previous module section. Students will need to refer to the procedures included on posters in order to effectively repeat a particular experiment.

PROCEDURE

Day 1

1. Remind the students that what we really want to be able to do is to make predictions about crater size. This will allow us to design the mission's impactor in such a way that it will create an appropriate-sized crater on the comet in order to gather the information needed to answer the questions from the science team.
2. Put up a graph of student-generated data on an overhead. Ask the students if they see any patterns in the data. Ask them what they mean by "pattern."
3. Put up the "[Common Patterns](#)" overhead. Briefly discuss each of the patterns. As you are discussing these patterns, ask your students to think about what that pattern would physically mean by providing some examples from everyday life. Suggested talking points:
 - Linear – The best-fit line is straight. The value on the y-axis goes up in a regular pattern with changes in the value on the x-axis. A linear pattern in your data would mean that as you change the value of the factor (mass, angle, etc), the resulting crater size changes in a similar way. Building a tower of blocks is a common example that illustrates this pattern. An increase in the number of building blocks is directly related to an increase in the height of the tower.

- Exponential – Best-fit line is a curve with an increasing slope. One possibility is that the value on the y-axis is the square of the value on the x-axis. In your data, this would mean that as you increase the factor you changed, the resulting crater size increased faster and faster. Everyday examples of exponential patterns are reflected in population increases or the distribution of chain letters.
- Cyclical Pattern – Some patterns repeat themselves in a regular way. The example pictured here is a cosine function – a pattern that you will learn more about in math classes. This would mean that as you changed the factor, certain values of the factor would produce the same results - like something "resetting" the system every so often. Cyclical patterns are reflected in changing tides, seasons, and shifting between days and nights.
- Changing Patterns – Patterns like this can be described in different sections. Patterns like this indicate that maybe different things are important at different points in the process. For instance, really low speeds of impact may have a different effect on the target body than really high speeds of impact. An everyday life example of changing patterns could be illustrated in sales. For instance, how many cars are sold from a particular lot each weekend within a month would most likely change from one weekend to the next.

Teacher Tip

It may be helpful to mention to students that while a best-fit line is an approximation, it usually goes through the mean of the plotted data.

For more practice with visually estimating a best-fit line, have students visit the following interactive Web site:

<http://www.learn.co.uk/default.asp?WCI=SubUnit&WCU=3658>

4. Ask the students if data can still be considered to show a pattern even if the data doesn't fall exactly on a line or a curve. Put up the "[Best-Fit Lines](#)" overhead and discuss the concept of best-fit lines by using an overhead marker and drawing in the best-fit line. Explain that best-fit lines can be determined mathematically, but that today the students will visually estimate a best-fit line. Students may need help with the concept of best-fit lines. For instance, some groups will tend to connect data in a dot-to-dot manner and then get bogged down in trying to predict complicated point-to-point trends. Focus the students on eyeballing a best-fit line or curve.
5. Distribute photocopies of student data charts and graphs. You may make these specific to the class or use representative examples that are particularly good with all your classes. Be sure that mass, velocity, angle of impact, and hopefully some variety of surface data are all represented within each class.
6. Have students work with partners to determine what patterns they think fit each data set and sketch in the best-fit line on the data.
7. Bring the class back together. Ask your students what patterns they found. Ask your students if there are any data points that don't seem to fit. Discuss those points with your class and talk about why you might exclude particular data points when looking for a pattern.
8. Go back to the "[Common Patterns](#)" overhead. Ask your students how patterns could be used to predict results for values outside of those that have been tested. Discuss how predictions might be made. Focus on using the line itself to make predictions, rather than on making mathematical predictions at this point.
9. Distribute the handout "[Looking for Patterns and Making Predictions, Part 1](#)". In this assignment, the students will use the graphs to make a few predictions and then test those predictions using the same lab equipment used to make the original tests. There will be a strong temptation among students to fudge data so that their predictions match actual events. Encourage them not to do this by pointing out that scientists make great discoveries when they find things they were not expecting in their data.

Technology Tip

Encourage students to use an electronic spreadsheet to create data tables and then a graph that can be used to display their results.

10. Assign "[Journal Assignment #6](#)" in Appendix D as homework.

Day 2

11. Ask students to share how their prediction testing experience went yesterday. Discuss ways in which they might be able to improve the accuracy of their predictions, such as collecting more data, mathematically calculating a best-fit line or curve, etc.
12. Talk about looking for patterns in the numbers. Look at the linear example in particular. Display and discuss the overhead "[Finding a Formula For a Line](#)." Start by asking the students to observe the graph. Ask them to describe the variables on the x and y-axis. Next, ask them to consider the formula $y=mx+b$. Ask if they are familiar with this formula. Review by describing examples of the formula shown on the transparency (e.g., (x,y) are the ordered pair, m is the slope of the line, and b is the y intercept). Go over the three steps used to determine the formula given a line. Use the examples provided: $[m=(14-10)/(6-4), m=4/2, m=2]$, $[b=2]$, and [formula, $y=2x+2$]. Finally, have the students practice by using the problems at: <http://www.bonita.k12.ca.us/schools/ramona/teachers/carlton/tutorialinteractives/inF-L/graphing/graphing2.html>
13. Assign "[Looking for Patterns and Making Predictions, Part 2](#)."
14. Students work through Part 2. They may need to be reminded when carrying out calculations in Part 2 that the formulas they have put together only work for a specific set of conditions. For example, they may have come up with a linear formula for the effect of mass on crater depth. However, the numbers in that formula will only work for masses with the impact velocity used in the experiment into the surface material used in the experiment. Question 4 on "Looking for Patterns and Making Predictions, Part 2" is asked to get students to think about this issue, but some students may need a slight push in that direction.

Teacher Tip

With more advanced students, you may want to extend beyond "Looking for Patterns and Making Predictions, Part 2" by introducing the kinetic energy formula. After discussing the formula, challenge students to look for a quadratic relationship by graphing the square of the velocity against the crater size.

Student Anticipations

This activity relies on the use of graphical representation of data to find trends useful for making predictions. Classroom data is not going to fall on to a simple line or curve in most cases, nor are your students going to derive an accurate formula for the prediction of crater size that could be applied in all cases. However, this activity gives them experience in looking for patterns in data, analyzing data points for accuracy and inclusion, and making the connection between the slope of the line and rates of change.

Tests of velocity changes on the classroom scale tend to show an almost linear relationship between crater diameter and velocity, despite the mathematical reality of the relationship. Changes in mass will also be a roughly linear relationship. Other experiments may or may not show easy patterns. If a collection of data is not showing a clear pattern, have the students think of possible explanations. Does the factor actually have an effect on crater size? Could this factor actually be more than one factor? Is there something about the way the experiment was conducted that might be giving a false impression of the effects of one of the variables?

15. Assign "[Journal Assignment #7](#)" in Appendix D as homework.

TEACHER RESOURCES

Web Sites

<http://mathforum.com/cgraph/cslope/mxplusb.html>

Lines and Slope

<http://math.rice.edu/~lanius/Algebra/stress.html>

Slope as Rate of Change

<http://www.bonita.k12.ca.us/schools/ramona/teachers/carlton/tutorialinteractives/inF-L/graphing/graphing2.html>

The Web site provides a student with a linear equation and a Cartesian grid. As the student plots two points, the program identifies if the points are located on the line. The student can press a button to see the equation graphed.

<http://www.learn.co.uk/default.asp?WCI=SubUnit&WCU=3658>

This online educational unit presents explanations and examples of best-fit lines using scatter graphs.

<http://www.ncfaculty.net/dogle/WWW107/notes/regress5.htm>

Criteria for Best-Fit Lines